

National Institute of Standards & Technology

Sample Certificate

Standard Reference Material[®] 2517

Wavelength Reference Absorption Cell – Acetylene ($^{12}\text{C}_2\text{H}_2$)

Serial No.: Sample

This Standard Reference Material (SRM) is intended for use in calibrating the wavelength scale of wavelength measuring equipment in the spectral region from 1513 nm to 1541 nm. SRM 2517 is an optical-fiber-coupled absorption cell containing acetylene ($^{12}\text{C}_2\text{H}_2$) gas. Acetylene has more than 50 accurately measured absorption lines in the 1500 nm wavelength region.

Certified Wavelength Values: The vacuum wavelengths of absorption lines in the R and P branch of the $\nu_1 + \nu_3$ rotational-vibrational band of $^{12}\text{C}_2\text{H}_2$ have been measured previously to high accuracy by several independent research groups [1,2]. These literature values for the vacuum wavelengths were adjusted for the pressure shift due to the collisions between acetylene molecules at the 27 kPa (200 Torr) pressure within the SRM cell to obtain the certified wavelength values for this SRM. Details of the measurement procedure and data analysis for the determination of the pressure shift can be found in reference [3]. A spectrum of the absorption band is shown in Figure 1 and certified wavelength values are given in Table 1. Figure 2 shows a higher resolution scan near line P9. The wavelengths of the lines listed in Table 1 are certified with an expanded uncertainty of ± 0.0006 nm (coverage factor $k = 2$).

Expiration of Certification: The certification of this SRM is indefinite within the measurement uncertainties specified, provided the SRM is handled, stored, and used in accordance with the instructions given in this certificate.

Measurement Conditions and Procedure: The long term stability of acetylene and the use of fundamental molecular absorption lines render the SRM insensitive to changes in environmental conditions. The purpose of the certification procedure is to verify that the unit contains the correct pressure of $^{12}\text{C}_2\text{H}_2$ gas and has no significant contaminants that produce additional absorption lines. Measurements were made using a 0.05 nm resolution optical spectrum analyzer. Spectra similar to those shown in Figures 1 and 2 were taken of each SRM unit and compared with measurements of reference absorption cells maintained at NIST.

Storage and Handling: The protective caps provided for the FC/PC fiber connectors should be replaced when the SRM is not in use. This SRM is intended to be used in a laboratory environment near ambient room temperature ($22\text{ }^\circ\text{C} \pm 5\text{ }^\circ\text{C}$). Optical alignment is critical; the user should avoid exposing the unit to large temperature variations, temperature cycling, or mechanical shock, as these may cause the optical alignment to degrade. Optical misalignment affects the throughput of the SRM but will not shift the centers of the absorption lines. A more serious, but less likely problem is cell breakage or leakage. The unit should be replaced if the linewidths or depths differ significantly from those shown in Figures 1 and 2 (when measured using comparable resolution).

Development of the SRM and supporting measurements were performed by S.L. Gilbert and W.C. Swann of the NIST Optoelectronics Division.

Gaithersburg, MD 20899
Certificate Issue Date: 28 October 1998

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Statistical consultation was provided by C.M. Wang of the NIST Statistical Engineering Division.

The support aspects involved in the preparation, certification, and issuance of this SRM were coordinated through the Standard Reference Materials Program by R.J. Gettings.

Table 1. Certified Wavelengths for SRM 2517

Literature values from Reference [1] adjusted for the pressure shift due to the 27 kPa (200 Torr) cell pressure. These vacuum wavelengths of the $\nu_1 + \nu_3$ band of $^{12}\text{C}_2\text{H}_2$ are certified with an expanded uncertainty of ± 0.0006 nm (coverage factor $k = 2$).

R Branch	nm	P Branch	nm
25	1513.2007	1	1525.7607
24	1513.5839	2	1526.3147
23	1513.9733	3	1526.8751
22	1514.3690	4	1527.4419
21	1514.7710	5	1528.0151
20	1515.1793	6	1528.5946
19	1515.5939	7	1529.1806
18	1516.0148	8	1529.7730
17	1516.4419	9	1530.3718
16	1516.8754	10	1530.9770
15	1517.3152	11	1531.5886
14	1517.7613	12	1532.2067
13	1518.2138	13	1532.8312
12	1518.6725	14	1533.4621
11	1519.1376	15	1534.0995
10	1519.6090	16	1534.7433
9	1520.0867	17	1535.3935
8	1520.5707	18	1536.0502
7	1521.0611	19	1536.7134
6	1521.5579	20	1537.3830
5	1522.0610	21	1538.0590
4	1522.5704	22	1538.7416
3	1523.0862	23	1539.4306
2	1523.6084	24	1540.1261
1	1524.1369	25	1540.8281

INSTRUCTIONS FOR USE

General Considerations: The SRM can be used to calibrate a wavelength measuring instrument in the 1510 nm to 1540 nm region. The wavelength calibration is vacuum wavelength; if the user requires the wavelength in air, the appropriate correction for the index of refraction of air must be applied (see Reference [4]). Depending on what type of instrument is being calibrated, a broadband source or a tunable narrowband source may be used.

Use With a Broadband Source: A broadband source in the 1500 nm region (such as a light emitting diode, white light, or amplified spontaneous emission source) is useful when calibrating a low resolution instrument such as a diffraction grating based optical spectrum analyzer or monochrometer. A schematic for this type of calibration is shown in Figure 3(a). Light from the broadband source is coupled into the SRM and the output (transmission through the SRM) is connected to the instrument that is being calibrated. The absorption lines of acetylene appear as dips in the spectrum of the light source (see Figure 1).

Use With a Narrowband Source: The SRM can be used to calibrate the wavelength scale of a tunable narrowband source in this region (such as a diode laser or fiber laser). Alternatively, a tunable source and the SRM can be used to check the calibration of a wavelength meter, as shown in Figure 3(b). The laser is tuned over one or more of the acetylene absorption lines. The transmission through the SRM is monitored by a detector; the transmitted power passes through a minimum at the center of an absorption line.

Suggested Procedure for Low-Accuracy Requirements; Calibration Uncertainty > 0.1 nm: Connect the light source (either broadband or narrowband, as discussed above) to one of the fiber connectors on the SRM unit using a single-mode optical fiber terminated with a clean FC/PC connector. After identifying the absorption lines by comparing to the spectrum in Figure 1, find the center or the minimum point of a line listed in Table 1. If the instrument has variable resolution, it is best to use a resolution of ≤ 0.2 nm. For this level of accuracy, the procedure used to find the line center can be quite simple: setting a cursor to the line center or minimum by eye is sufficient. If using a tunable source, simply tune it to the transmission minimum of the line, using tuning steps of ≤ 0.01 nm. Calibrate the instrument to the wavelength of this line (from Table 1) using the calibration procedure specified by the instrument manufacturer. The instrument's linearity can be checked by repeating the procedure for a different absorption line and comparing it to the value listed in Table 1.

Suggested Procedure for Moderate-Accuracy Requirements; Calibration Uncertainty in the Approximate Range of 0.01 nm to 0.1 nm: Connect the light source (either broadband or narrowband, as discussed above) to one of the fiber connectors on the SRM unit using a single-mode optical fiber terminated with a clean FC/PC connector. If the source power varies significantly with wavelength, divide the SRM transmission spectrum by the source spectrum to obtain a normalized trace. After identifying the absorption lines by comparing to the spectrum in Figure 1, make a high resolution scan of a line listed in Table 1. If the instrument has variable resolution, it is best to use a resolution of ≤ 0.1 nm with a data point density of at least one point every 0.005 nm. Find the wavelength readings on both sides of the line where the absorption is 50 % of the maximum; the line center is half-way between these two wavelength readings. Repeat this procedure five times and take the average of the five measurements for the line center. Calibrate the instrument to the center wavelength of this line (from Table 1) using the calibration procedure specified by the instrument manufacturer. The instrument's linearity can be checked by repeating the procedure for a different absorption line and comparing it to the value listed in Table 1.

Suggested Procedure for High-Accuracy Requirements; Calibration Uncertainty < 0.01 nm: *[Note: due to the presence of weak nearby lines, background slope, and interference fringes, this SRM is not recommended for a calibration with an uncertainty of less than 0.001 nm.]* Connect the light source (either broadband or narrowband, as discussed above) to one of the fiber connectors on the SRM unit using a single-mode optical fiber terminated with a clean FC/PC connector. Divide the SRM transmission spectrum by the source spectrum to obtain a normalized trace. After identifying the absorption lines by comparing to the spectrum in Figure 1, make a high resolution scan of a line listed in Table 1. If the instrument has variable resolution, it is best to use a resolution of ≤ 0.1 nm with a data point density of at least one point every 0.001 nm. Using a fitting technique such as the least squares technique, fit the absorption data to the appropriate lineshape (Lorentzian if the line shape is dominated by the molecular absorption profile, Lorentzian convoluted with the instrument's filter characteristics if the instrument contributes significantly to the profile). Details of line fitting procedure and potential errors sources can be found in Reference [3]. Calibrate the instrument to the center wavelength of this line (from Table 1) using the calibration procedure specified by the instrument manufacturer. The instrument's linearity can be checked by repeating the procedure for a different absorption line and comparing it to the value listed in Table 1.

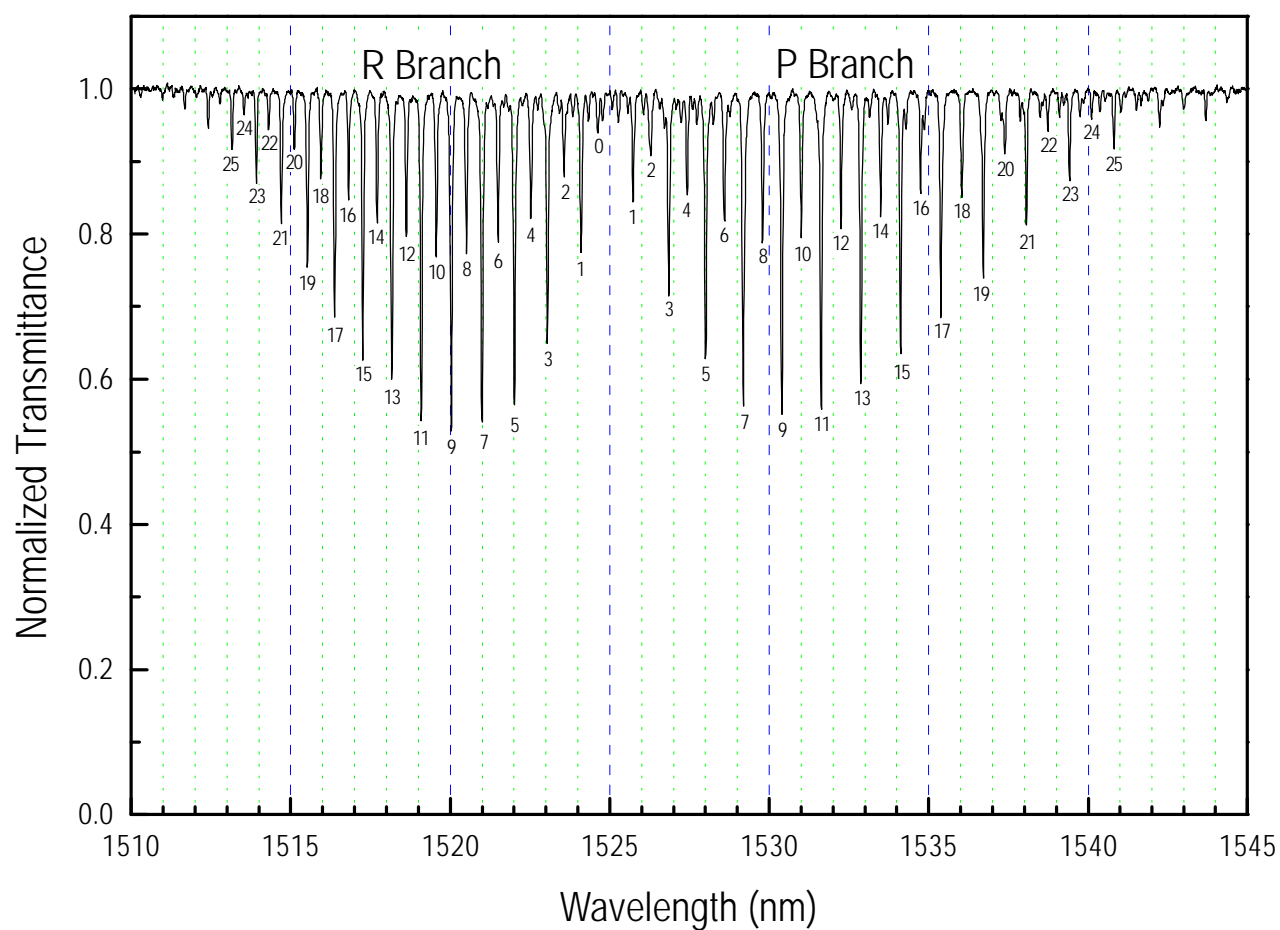


Figure 1. Acetylene ($^{12}\text{C}_2\text{H}_2$) spectrum taken by passing LED light through an absorption cell and recording the spectrum of the transmitted light using an optical spectrum analyzer with 0.05 nm resolution. This spectrum has been divided by the LED spectrum.

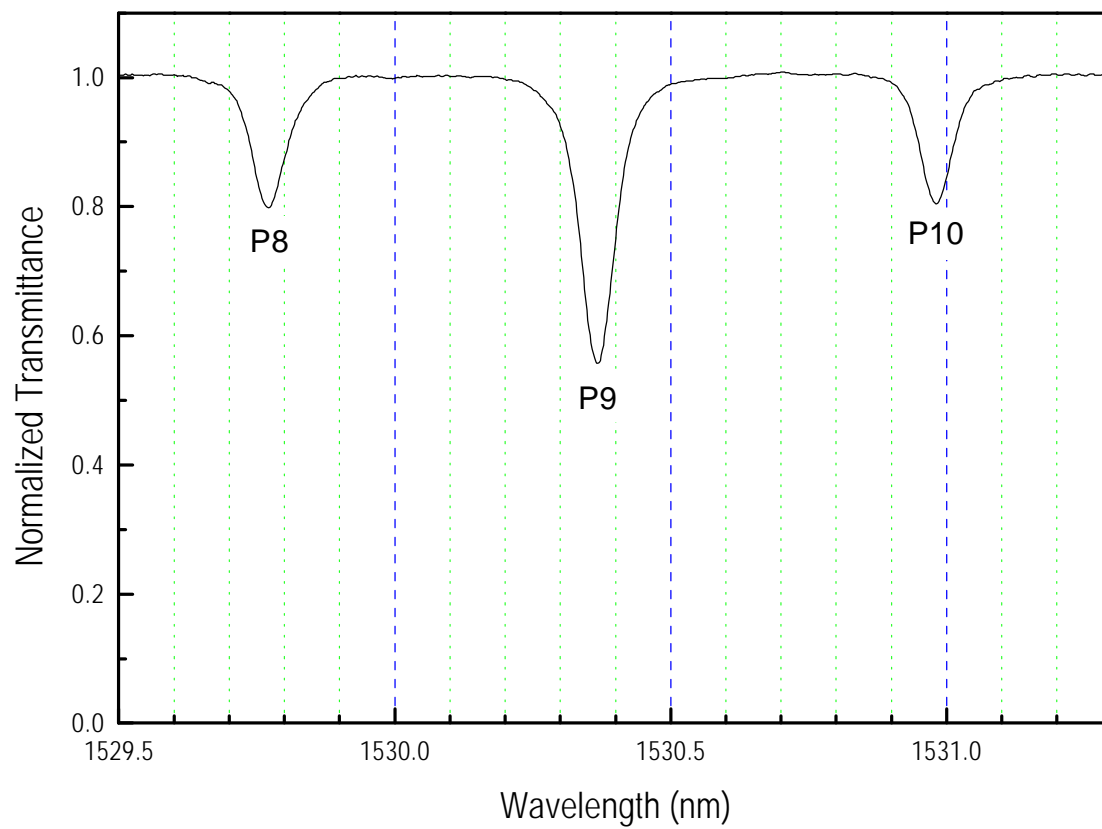


Figure 2. The P8, P9, and P10 lines from Figure 1 on an expanded wavelength scale to show lineshape.

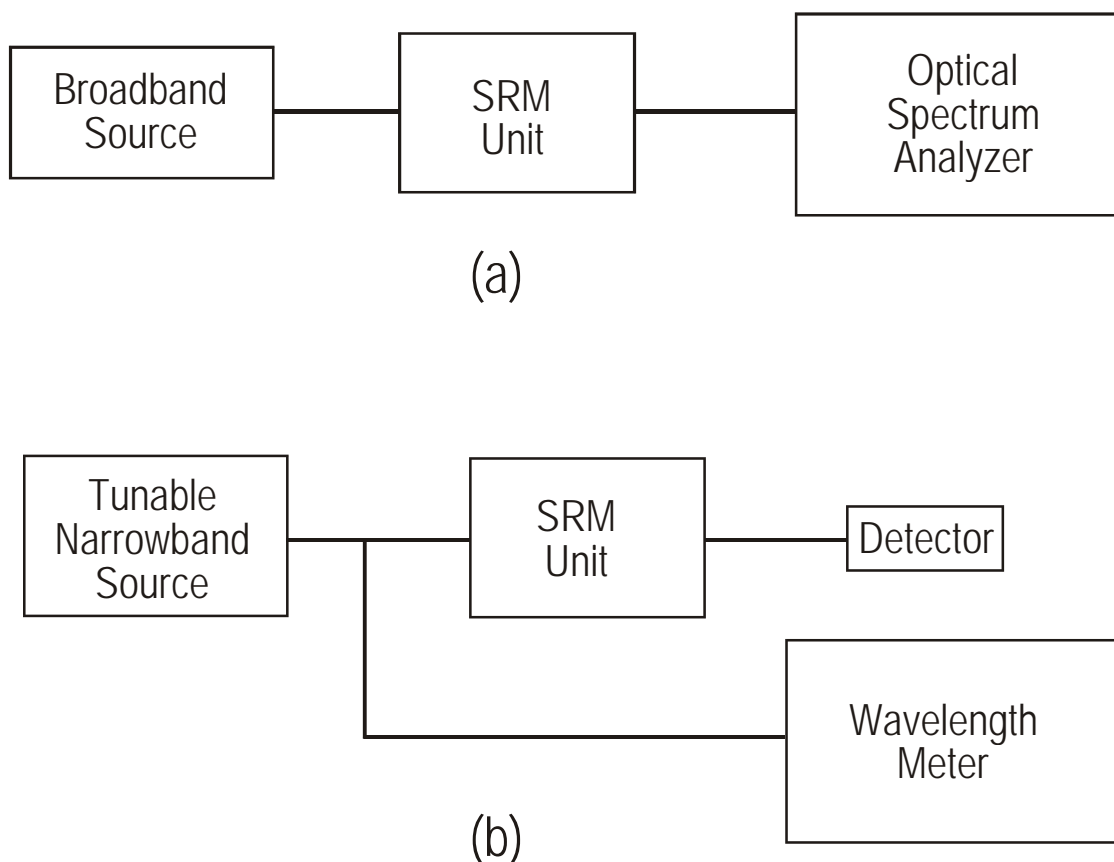


Figure 3. (a) Schematic of technique when using the SRM and a broadband source to calibrate an optical spectrum analyzer. (b) Schematic of technique when using the SRM and a narrowband source to calibrate a tunable laser or a wavelength meter. The wavelength meter is not required for a laser calibration.

REFERENCES

- [1] Nakagawa, K., Labachellerie, M., Awaji, Y., and Kourogi, M., "Accurate Optical Frequency Atlas of the 1.5- μm Bands of Acetylene," J. Opt. Soc. Am. B **13**, pp. 2708-2714, (1996).
- [2] Yoshida, T. and Sasada, H., "Near-Infrared Spectroscopy with a Wavemeter," J. Molec. Spectrosc. **153**, pp. 208-210 (1992); Guelachvili, G. and Rao, K.N., Handbook of Infrared Standards II, Academic Press, San Diego, CA, pp. 564-568 (1993).
- [3] Gilbert, S.L., and Swann, W.C., "Standard Reference Materials: Acetylene $^{12}\text{C}_2\text{H}_2$ Absorption Reference for 1510–1540 nm Wavelength Calibration – SRM 2517," NIST Special Publication 260-133 (1997). In Press.
- [4] Edlen, B., "The Refractive Index of Air," Metrologia, **2**, p. 12, (1966); CRC Handbook of Chemistry and Physics 77th Ed., pp. 10-266, (1996).

It is the responsibility of users of this SRM to assure that the certificate in their possession is current. This can be accomplished by contacting the SRM Program at (301) 975-6776 (select "Certificates"), Fax (301) 926-4751, e-mail srminfo@nist.gov, or via of the Internet <http://ts.nist.gov/srm>.